DIPARTIMENTO DI ELETTRONICA, INFORMAZIONE E BIOINGEGNERIA

Politecnico di Milano

Machine Learning (Code: 097683)

January 21, 2020

Surname:	
Name:	
Student ID:	
Row:	Column:

Time: 2 hours 30 minutes | Prof. Marcello Restelli | Maximum Marks: 34

- The following exam is composed of **10 exercises** (one per page). The first page needs to be filled with your **name, surname and student ID**. The following pages should be used **only in the large squares** present on each page. Any solution provided either outside these spaces or **without a motivation** will not be considered for the final mark.
- During this exam you are **not allowed to use electronic devices**, such as laptops, smartphones, tablets and/or similar. As well, you are not allowed to bring with you any kind of note, book, written scheme and/or similar. You are also not allowed to communicate with other students during the exam.
- The first reported violation of the above mentioned rules will be annotated on the exam and will be considered for the final mark decision. The second reported violation of the above mentioned rules will imply the immediate expulsion of the student from the exam room and the **annulment of the exam**.
- You are allowed to write the exam either with a pen (black or blue) or a pencil. It is your responsibility to provide a readable solution. We will not be held accountable for accidental partial or total cancellation of the exam.
- The exam can be written either in **English** or **Italian**.
- You are allowed to withdraw from the exam at any time without any penalty. You are allowed to leave the room not early than half the time of the duration of the exam. You are not allowed to keep the text of the exam with you while leaving the room.
- **Three of the points will be given on the basis on how quick you are in solving the exam.** If you finish earlier than 45 min before the end of the exam you will get 3 points, if you finish earlier than 30 min you will get 2 points and if you finish earlier than 15 min you will get 1 point (the points cannot be accumulated).
- The box on Page 12 can only be used to complete the Exercises 9 and/or 10.

Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8	Ex. 9	Ex. 10	Time	Tot.
/ 5	/ 5	/ 5	/ 2	/ 2	/ 2	/ 2	/ 2	/ 3	/ 3	/ 3	/ 34

Exercise 1 (5 marks)

Describe and compare the following regression techniques: **ridge regression** and **lasso**.

Exercise 2 (5 marks)

Give the definition of **valid** kernel and describe how valid kernels can be built.

Exercise 3 (5 marks)

Describe the properties of the Bellman operators.

Exercise 4 (2 marks)

```
1  load iris_dataset.mat
2  x = zscore(irisInputs(1, :)');
3  t = zscore(irisInputs(2, :)');
4  n_train = size(x, 1); theta = 1; sigma = 1;
5  GPmodel = fitrgp(x, t, 'KernelFunction', 'squaredexponential');
6  x_new = linspace(min(x), max(x), 40)';
7  K = gaussKer(x, x, theta) + sigma * eye(n_train);
8  for ii = 1:40
9    Kstar = gaussKer(x_new(ii), x, theta);
10   Kstarstar=gaussKer(x_new(ii),x_new(ii),theta)+sigma^2;
11   t_new(ii) = Kstar * pinv(K) * t;
12   t_var(ii) = Kstarstar - Kstar * pinv(K) * Kstar';
13 end
```

1. Describe the operations performed by the MatLab code snippet above.
2. Which kind of problem are we solving with this code? Name the algorithm we are applying.
3. Which are the parameters one can modify to tune the algorithm in this snippet? Identify them and provide an interpretation for each one of them.

- Line 1 – 4
- Line 5
- Line 6
- Line 7
- Line 8 – 13

Exercise 5 (2 marks)

You fitted a Linear Model to your data set using the Least Square method. Nonetheless, you are thinking about use some regularization techniques, i.e., apply Ridge Regression. Tell if the following statements are likely to be true or false:

1. Using the Ridge Regression will decrease your Irreducible Error;
2. Using the Ridge Regression will decrease the Bias of your model;
3. Using the Ridge Regression will decrease the Variance of your model;
4. Using the Ridge Regression will decrease your Reducible Error.

Provide motivations to your answers.

Exercise 6 (2 marks)

Tell if the following statements about the Thompson Sampling (TS) algorithm are true or false. Motivate your answers.

1. The more an arm has been pulled, the more the posterior distribution of its reward is peaked;
2. The TS algorithm is suitable to solve problems in the stochastic and adversarial MAB classes;
3. The TS algorithm uses specific information about the reward being Bernoulli distributed;
4. The TS algorithm is a deterministic algorithm.

Exercise 7 (2 marks)

For each one of the following dichotomies in MDP modeling provide examples of problems with the listed characteristics:

1. Finite/infinite actions;
2. Deterministic/stochastic transitions;
3. Deterministic/stochastic rewards;
4. Finite/indefinite/infinite horizon.

Exercise 8 (2 marks)

Consider a classification problem having more than two classes. Propose a method to deal with multiple classes in each one of the following methods:

1. K-Nearest Neighbors;
2. Näive Bayes;
3. Linear regression;
4. Logistic regression.

Exercise 9 (3 marks)

Consider the following MDP with three states $\mathcal{S} = \{A, B, C\}$ (C is terminal), three actions $\mathcal{A} = \{h, l, s\}$ given a specific policy π, given the following trajectories:

$$(A, l, 3) \to (B, s, 2) \to (B, h, 1) \to (C)$$
$$(A, h, 2) \to (A, h, 1) \to (B, s, 3) \to (C)$$
$$(B, l, 1) \to (A, l, 1) \to (B, l, 0) \to (C)$$

1. Can you tell without computing anything if by resorting to MC with every-visit and first-visit approach you will have different results?
2. Compute the state-action function for each state/action pairs with the two aforementioned methods.
3. What prescribes the greedy policy corresponding to the MC every-visit estimation?

Exercise 10 (3 marks)

You are given an initial parameter $\mathbf{w}^{(0)} = [0\ 1\ 1]^\top$, and a loss function of the form:

$$J(\mathbf{w}) = \frac{1}{2N} \sum_{n=1}^{N} \log \left[(\mathbf{w}^\top \mathbf{x}_n - t_n)^2 + 1 \right].$$

1. Derive the update formula given by the gradient descent;
2. Compute the value of the parameter $\mathbf{w}^{(1)}$, obtained by using the datum $\mathbf{x}_1 = [3\ 3\ -2]^\top$, $t_1 = 4$ and a learning rate $\alpha = \frac{5}{30}$;
3. What changes are necessary if we want to perform a batch update with $K = 10$ data at the same time? Explain and justify the procedure.